

Recent Developments in Pump Turbines

HydroVision

Charlotte July 27 – 30, 2010, USA

Dr. Manfred Sallaberger

Andritz Hydro Zurich, Switzerland

Drivers of the Pumped Storage upswing

Market Requirements

- **Grid stability**
 - more wind power
 - more bottle necks
 - risk of black outs
- **Trading in the electricity market**
 - short term peaking
 - value of reserve capacity
- **Ancillary services**
 - Compensate the non-dispatchable renewables (wind, solar)

Development of Technology

- **Regulating possibility also in pumping mode**
 - Variable speed
 - Hydraulic short circuit
- **Reliability and smooth operating behavior also with challenging operation of units**
 - frequent start-stops
 - rapid load changes

Challenges to Pump Turbines

Low submergence
- minimize civil costs

Avoid cavitation damage

Smooth and stable operation

Extended operation range
- Low part load operation

Optimized performance characteristics
- Power input/output
- High efficiency

Wide head range

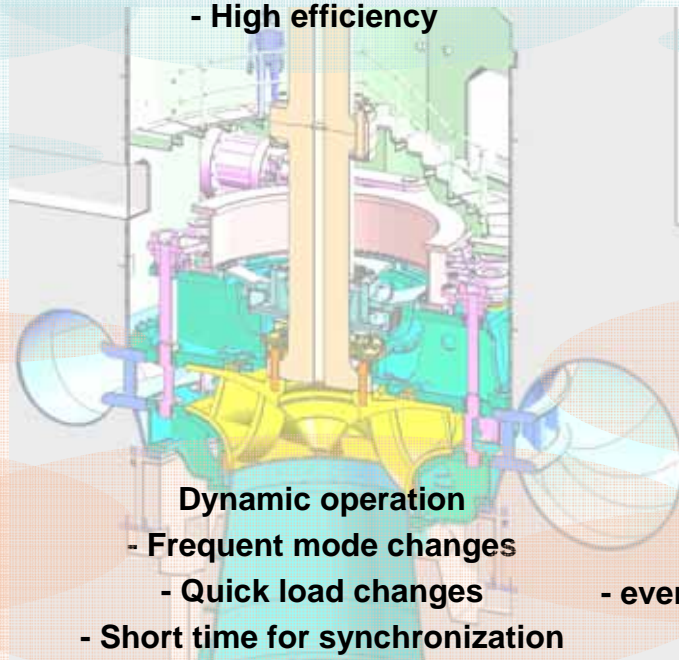
Cope with frequency variation

Structural integrity shall
- ensure service life
- Static and dynamic loads

Dynamic operation
- Frequent mode changes
- Quick load changes
- Short time for synchronization

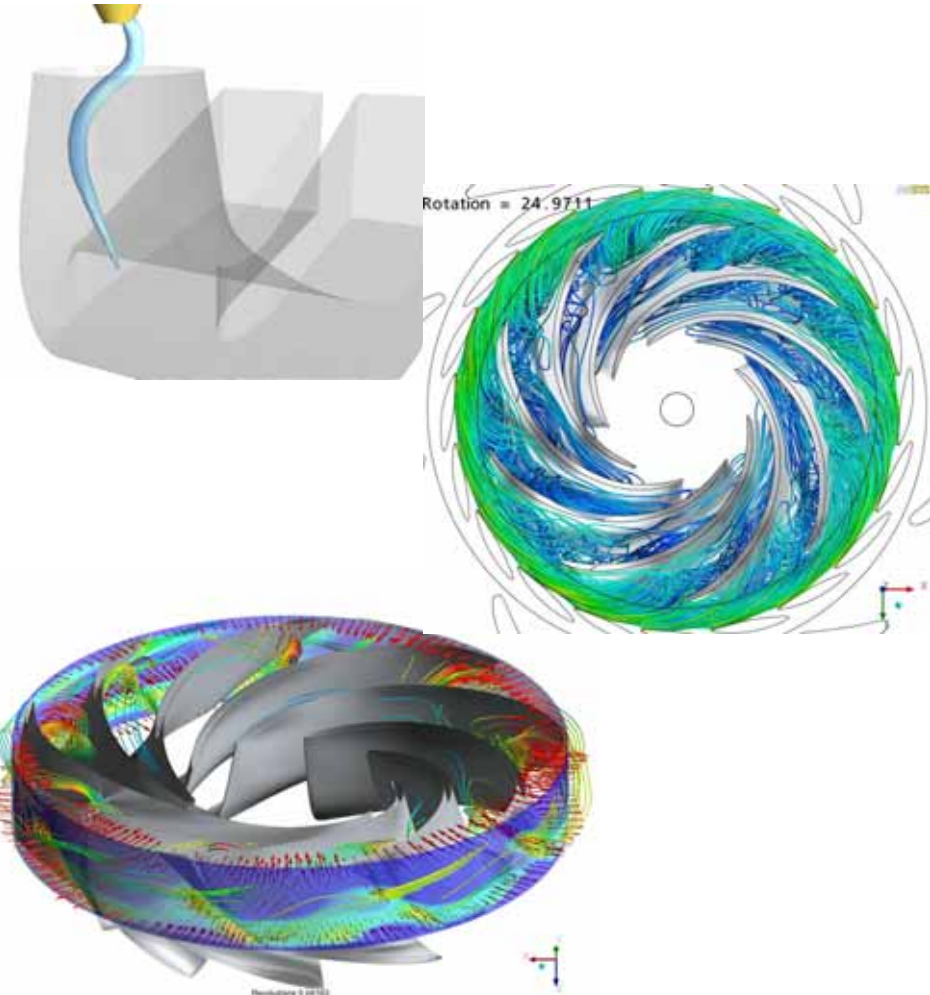
High reliability
- even with frequent load changes

Ongoing Research in Pump Turbines



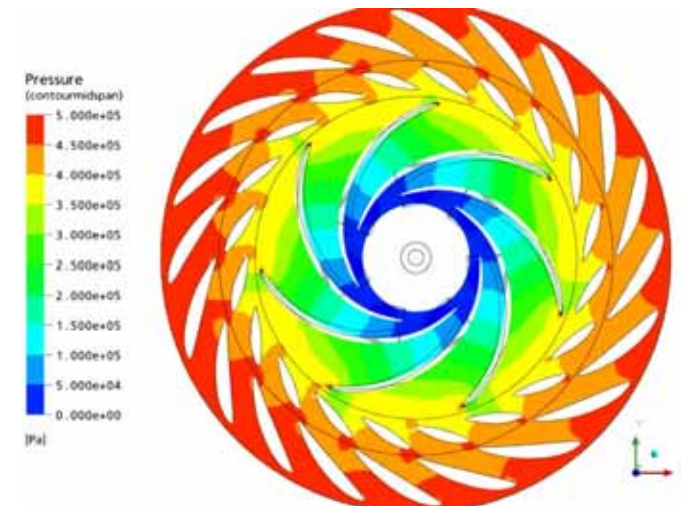
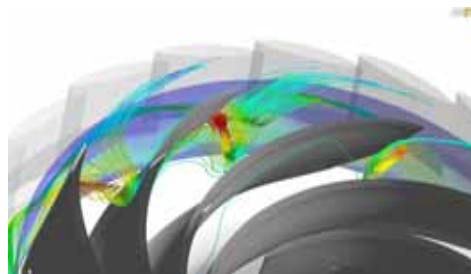
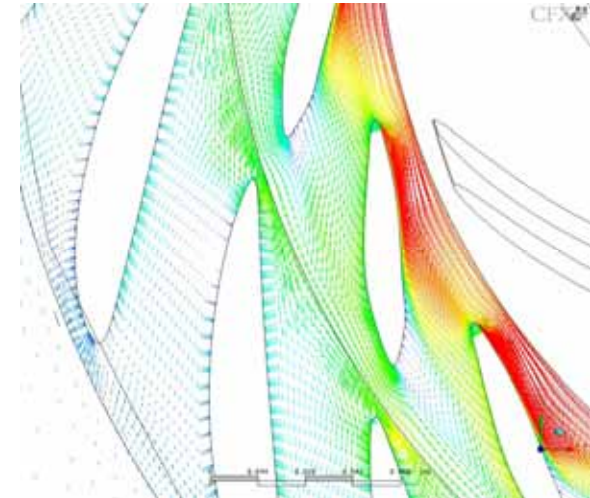
Research on Unsteady Phenomena in Pump-turbines

- **Draft tube vortex in turbine part load operation**
 - Increased pressure fluctuations in draft tube
 - Rough operation of pump-turbine
- **Low part load operation**
 - Aeration admits extension of operation range
 - Detailed investigation ongoing
- **Stability with synchronization in turbine operation**
 - Fluctuation of torque and speed of unit
 - Long duration for Synchronization



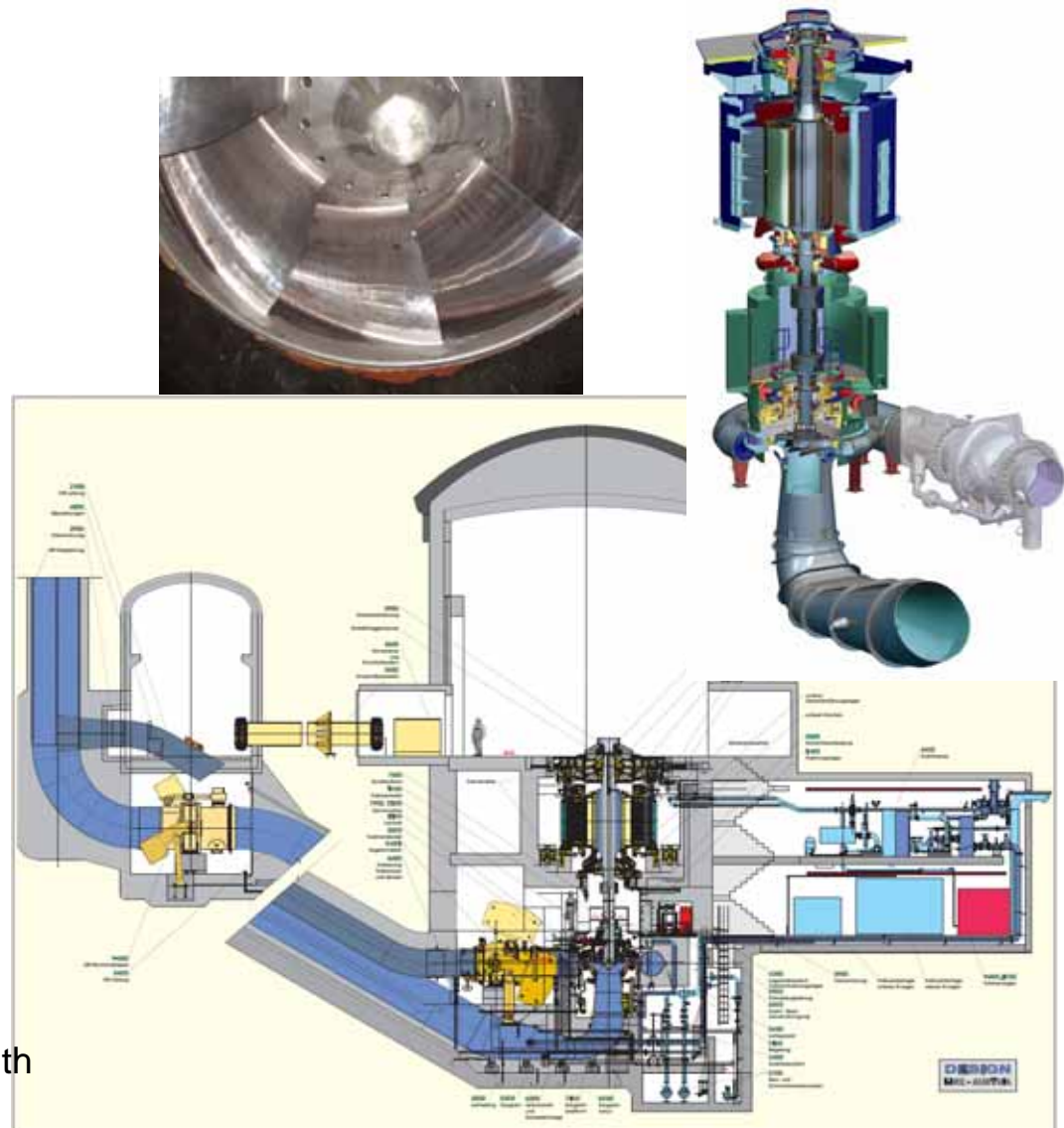
Research on Unsteady Phenomena in Pump-turbines

- **Pump-stability at high head**
 - Drop of head-flow characteristics at high heads
 - Unstable operation or start-up possible
- **Rotor – stator Interaction**
 - Unsteady pressure load on runner and stationary components
 - Rough operation of pump turbine

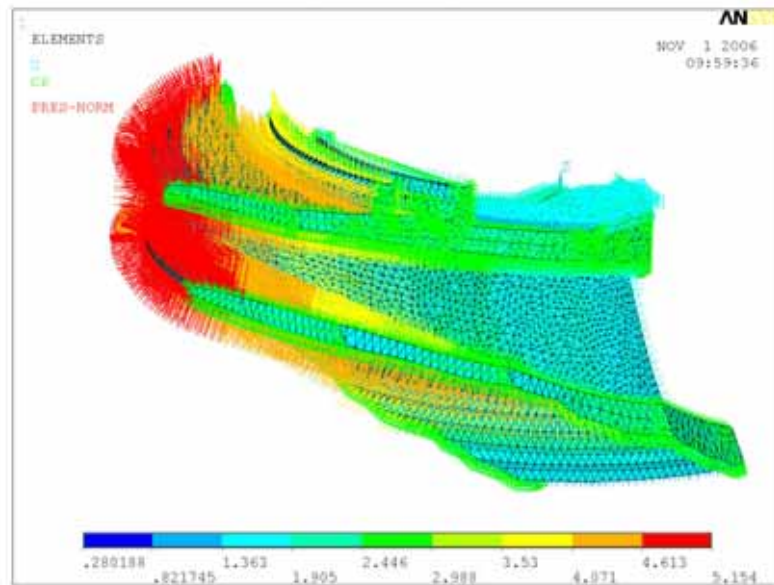


Hintermuhr

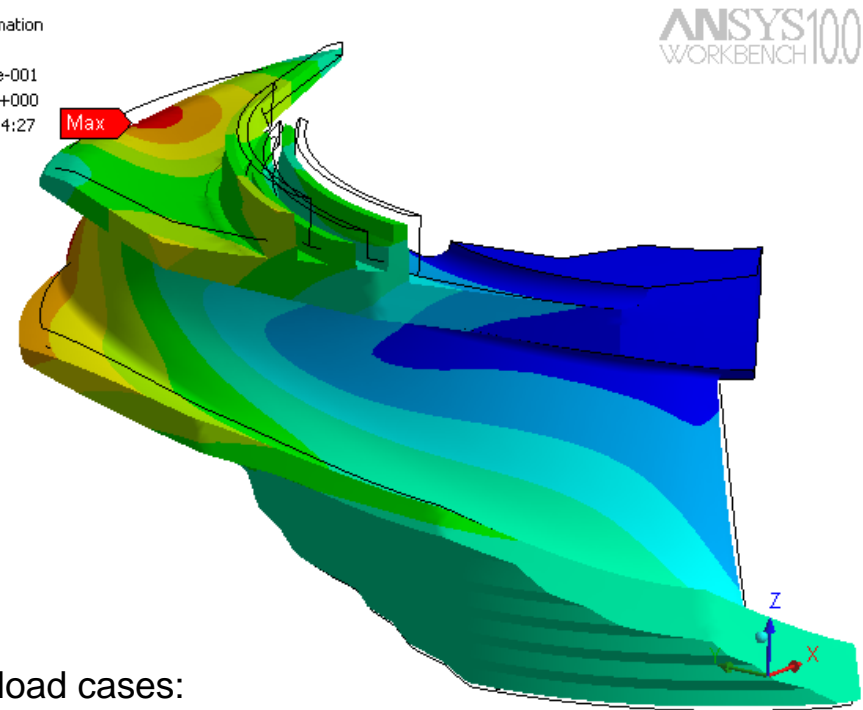
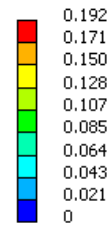
- **Customer: Salzburg AG, Austria**
 - Runner outlet diameter $D1 = 1870$ mm
 - Head range 455 m – 517 m
 - Max power 71.5 MW
 - **Speed $n = 1000$ rpm**
 - Specific speed 126
- Scope of supply:
- 1 Pump Turbine
 - Motor Generator
 - Governor
 - 1 Butterfly valve
 - 1 spherical valve
-
- Existing cavern for two Pelton units
 - Guide vanes and labyrinth rings coated with tungsten carbide SXH70



Structural Integrity Static Analysis



Total Deformation
mm
Max: 1.922e-001
Min: 0.000e+000
2006/11/1 14:27



Standard FEA for a pump turbine runner includes four load cases:

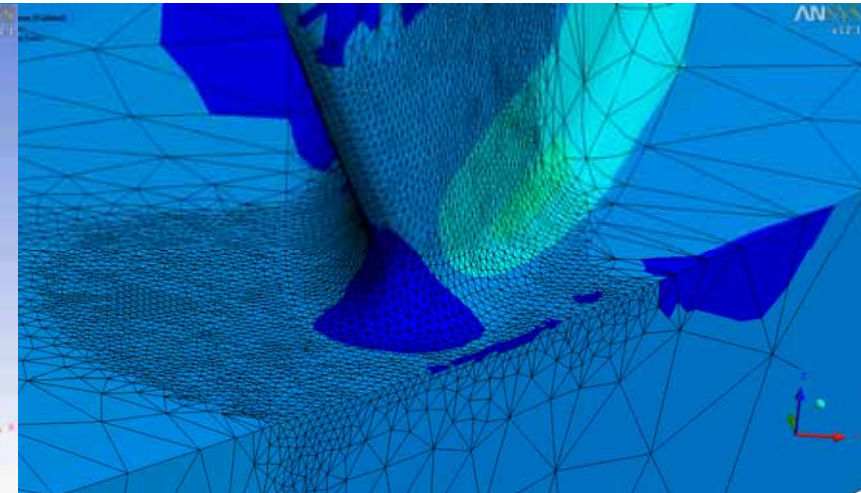
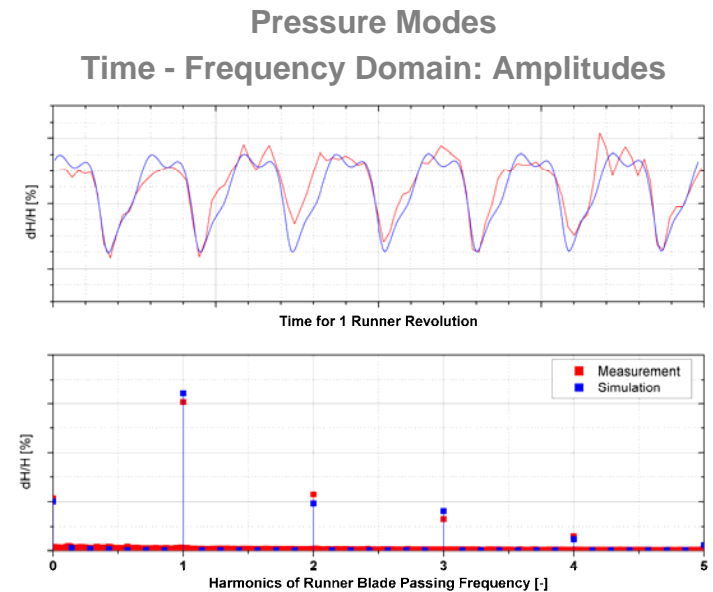
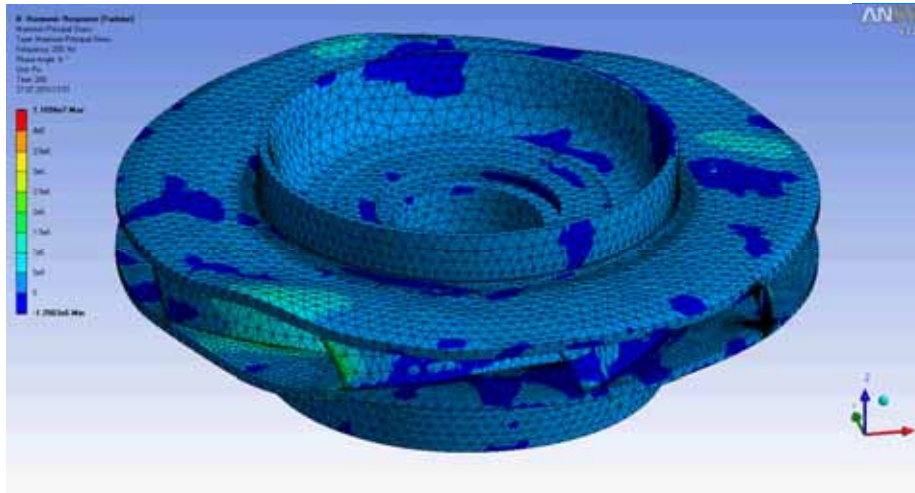
- Load case 1: Pump operation at maximum head (Pu-Hmax)
- Load case 2: Pump operation at minimum head (Pu-Hmin)
- Load case 3: Turbine operation at maximum head (Tu-Hmax)
- Load case 4: Runaway, i.e. speed no load, centrifugal load without torque

Structural Integrity

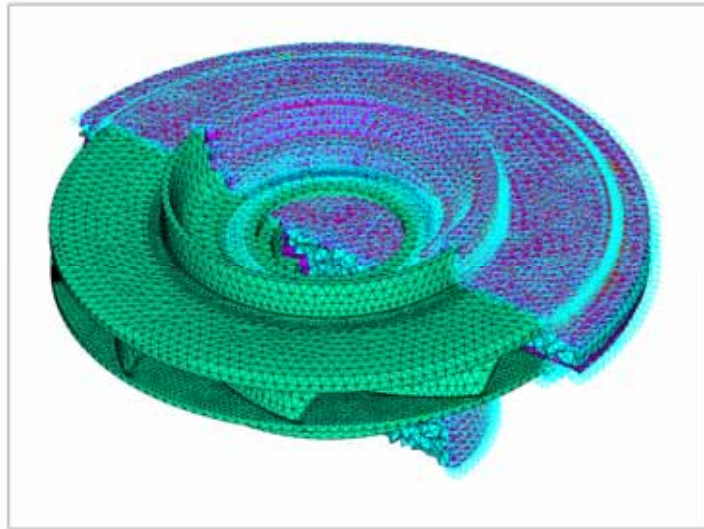
Dynamic Analysis

- Dynamic blade load from unsteady CFD
- FE analysis for specific frequencies (Harmonic response)

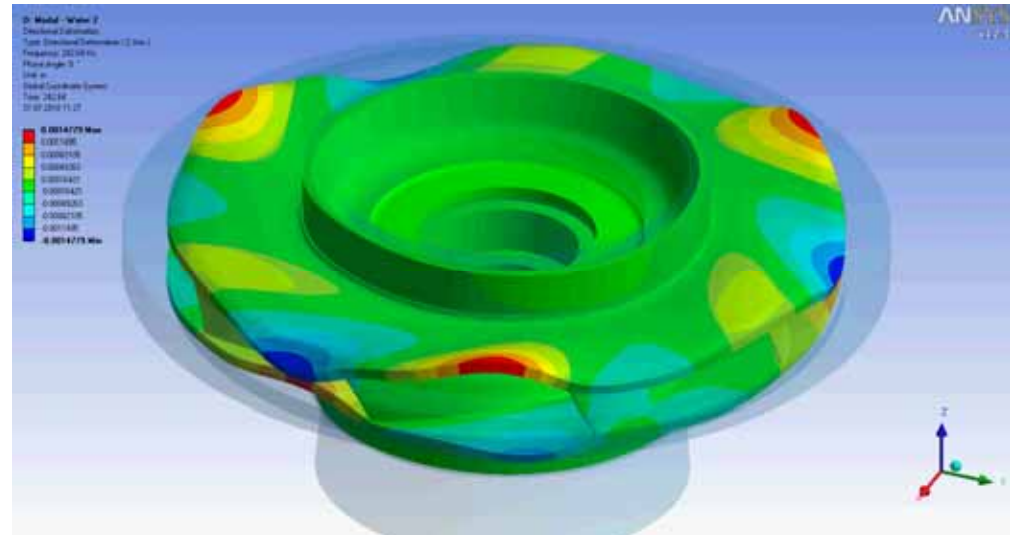
Distribution of Principle Stress



Structural Integrity Modal Analysis



Node diameter 3
counter phase mode between hub and shroud



- Natural frequency of runner including added mass effect of water and casing or walls
- Natural frequency of critical mode needs sufficient offset from exciting frequency
- First 10 natural frequencies investigated

Vianden M11

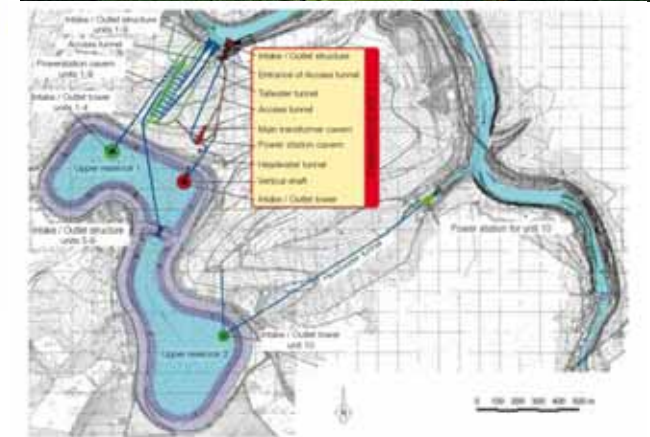
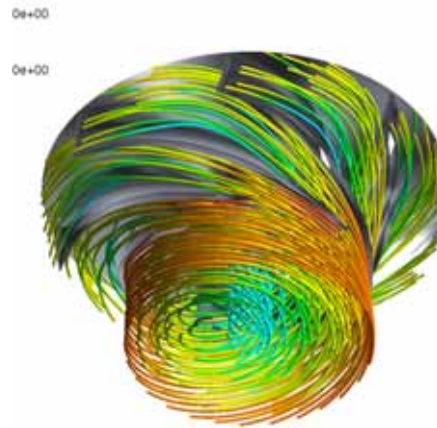
- **Customer: Societe Electrique de l'Our**

Extension of existing pumped storage plant
from 1.1 MW to 1.3 MW

- Runner Diameter D1 4286 mm
- Head range H 269.4 m – 294.6 m
- Max power P 200.4 MW
- Speed n 333.33 rpm
- Specific speed nsq 156

Scope of supply:

- 1 Pump Turbine
- 1 Motor/Generator, governor
- 1 Spherical valve
- Draft tube gate
- Single guide vane servo motors
- Mechanical synchronization of guide vane openings by synchronization ring
- Hydraulically pre-stressed guide vane bearings

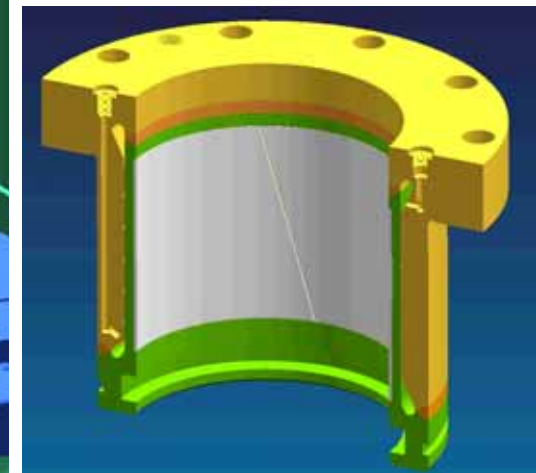
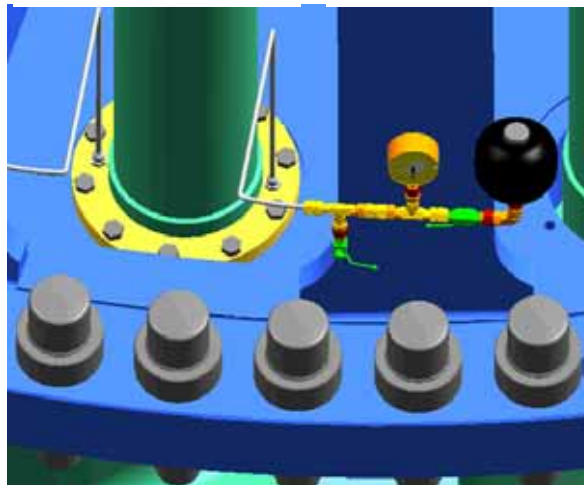
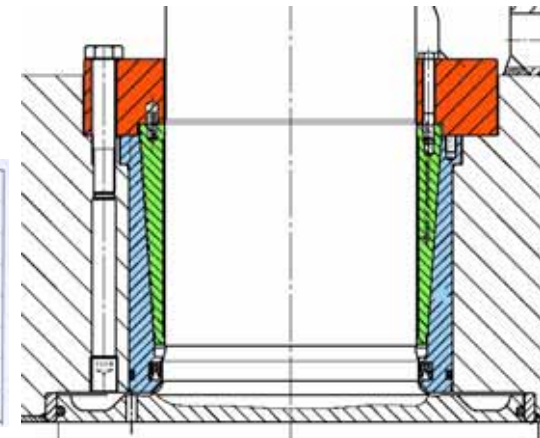
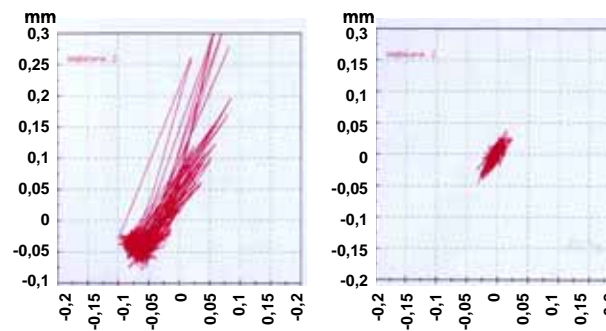


Vianden M11

- Hydraulically pre-stressed guide vane bearings

- Easy to install
- Easy to adjust
- Already tested in pump turbine rehab
- Applicable for replacement of existing conventional bearings

Displacement of wicket gate center

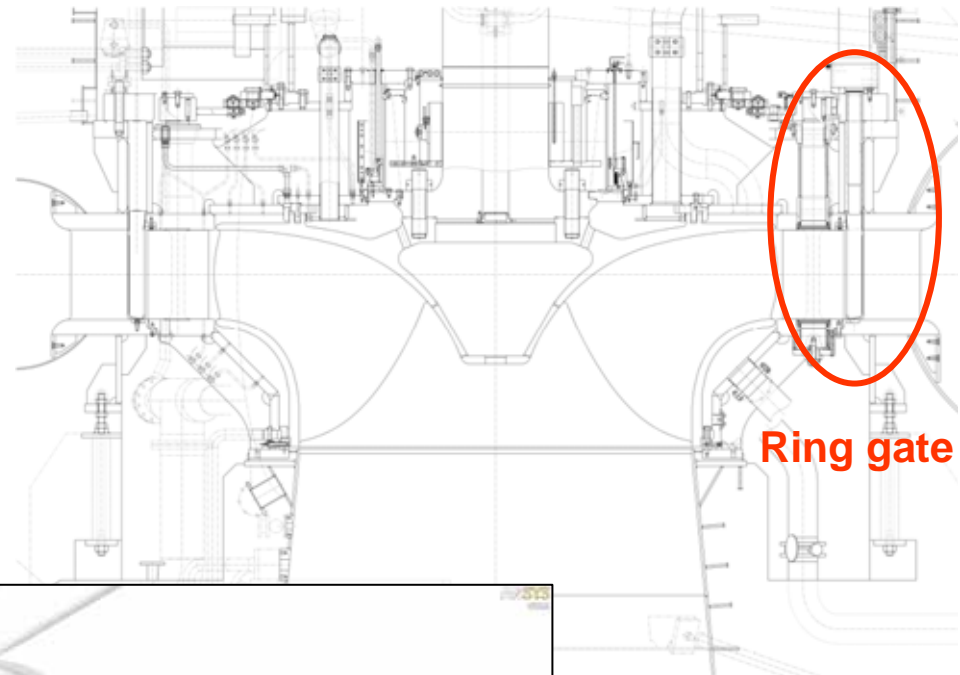


Baixo Sabor Montante

- **Customer: EDP, Portugal**
- Runner Diameter D1 4112 mm
- Head range H 68.8 m – 104.6 m
- Max power P 76.9 MW
- Speed n 214.29 rpm
- Specific speed nsq 212

Scope of supply:

- 2 Pump Turbines
- Motor/Generator
- Governor
- Ancillary equipment
- Hydraulic steel structures
- Wide head variation
- Equipped with ring gate

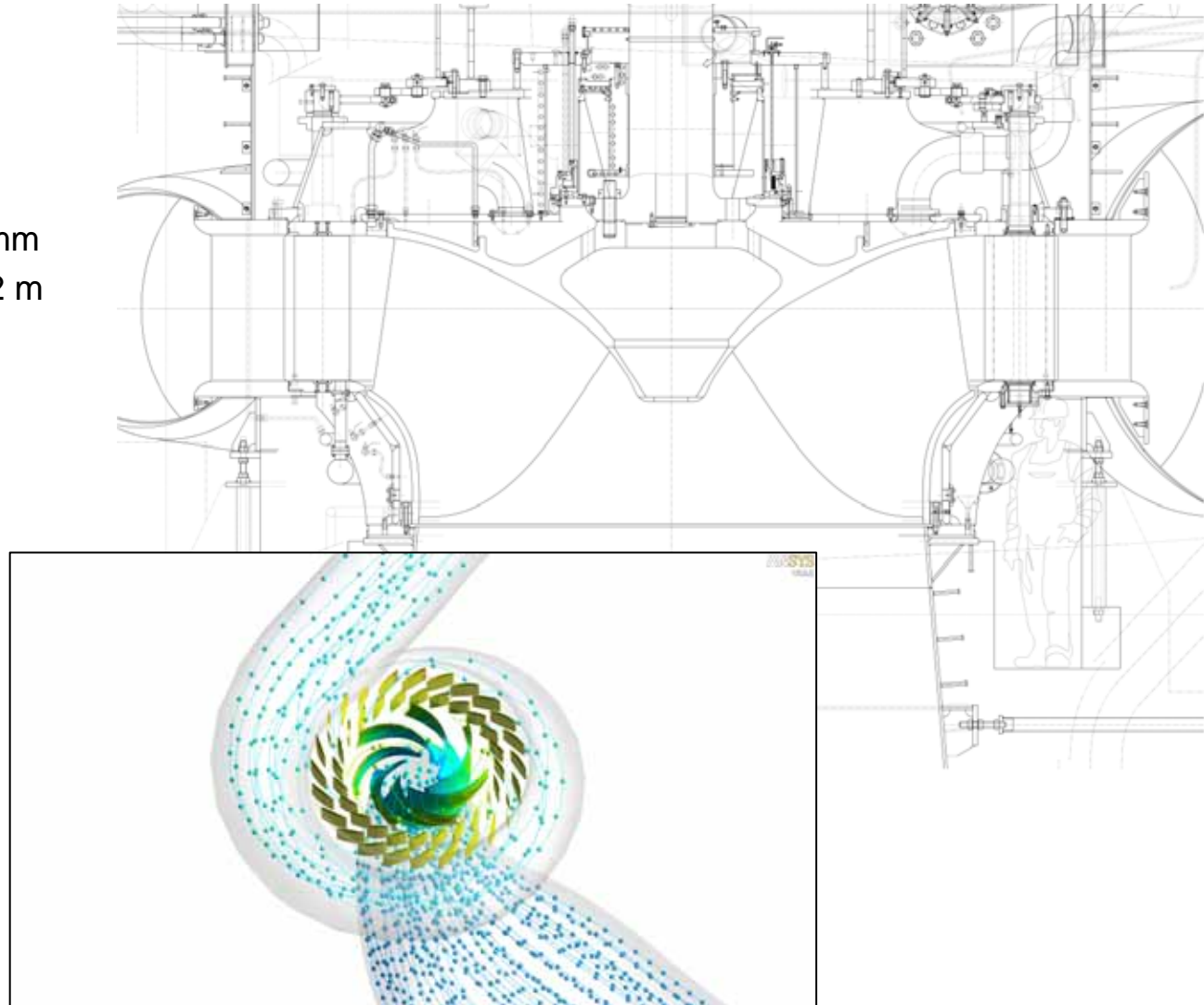


Baixo Sabor Jusante

- **Customer: EDP, Portugal**
- Runner Diameter D1 3948 mm
- Head range H 26.2 m – 35.2 m
- Max power P 17.8 MW
- Speed n 150 rpm
- Specific speed nsq 264

Scope of supply:

- 2 Pump Turbines
 - Motor/Generator
 - Governor
 - Ancillary equipment
 - Hydraulic steel structures
-
- Wide head variation



Successful designs of Pump turbines

Projekt	Head [m]	Power [MW]	Runner diameter [mm]	Speed [rpm]	Country	Status
Zarnowiec	127.5	187.6	6008	166.67	Poland	In Operation
Tongbai	288.8	306.0	4802	300	China	In Operation
Lang Ya Shan	152.9	165.7	4700	230.77	China	In Operation
Nestil	1065.7	141.2	2263	600	Switzerland	In Operation
Yixing	420	262	4394	375	China	In Operation
Hintermuhr	517.0	71.9	1870	1000	Austria	In Operation
Feldsee	547.8	72.7	1919	1000	Austria	In Operation

Baixo Sabor Montante	104.6	76.9	4112	214.29	Portugal	Hydraulic Design
Baixo Sabor Jusante	35.2	17.9	3948	150	Portugal	Hydraulic Design
Vianden M11	294.6	200.4	4286	333.33	Luxembourg	Hydraulic Design

Continuous development of technology

- Unsteady flow simulation
- Structural analysis, static and dynamic
- Rotor – Stator interaction

Application of modern technology in hydraulic and mechanical design provide

- High reliability
- Quick load changes
- Extension of operation range
- Resistance against erosion

Continuous experience in projects

- Wide range of application
- Innovative solutions

ANDRITZ Hydro is well prepared for the challenges in pumped storage

